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Published in:

Journal of Child Psychology and Psychiatry

Publication date:

2010

Document Version

Publisher's PDF, also known as Version of record

[Link to publication in Tilburg University Research Portal](#)

Citation for published version (APA):

Abubakar, A., Holding, P., van de Vijver, F. J. R., Newton, C. R. J. C., & van Baar, A. L. (2010). Children at risk for developmental delay can be recognised by stunting, being underweight, ill health, little maternal schooling or high gravidity. *Journal of Child Psychology and Psychiatry*, 51(6), 652-659.

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Children at risk for developmental delay can be recognised by stunting, being underweight, ill health, little maternal schooling or high gravidity

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Aims: To investigate markers of risk status that can be easily monitored in resource-limited settings for the identification of children in need of early developmental intervention. **Methods:** Eighty-five children in Kilifi, Kenya, aged between 2 and 10 months at recruitment, were involved in a 10-month follow-up. Data on developmental outcome were collected through parental report using a locally developed checklist. We tested for the unique and combined influence of little maternal schooling and higher gravidity, anthropometric status (being underweight and stunting) and poor health on the level of developmental achievement and the rate of acquisition of developmental milestones. **Results:** A model with all five predictors showed a good fit to the data ($\chi^2(21, N = 85) = 23.00, p = .33$). Maternal schooling and gravidity and child's stunting were found to predict the rate of developmental achievements ($\beta = .24, \beta = .31$, and $\beta = .41$, respectively). Being underweight, ill-health, stunting and gravidity predicted initial developmental status ($\beta = -.26, \beta = -.27, \beta = -.43$, and $\beta = -.27$). **Conclusions:** Slow rates of developmental achievement can be predicted using these easy-to-administer measures and the strongest relationship with risk was based on a combination of all measures. **Key words:** Latent growth curves, children, Africa, stunting, underweight, maternal schooling, health.

An estimated 200 million children in developing countries fail to achieve their developmental and cognitive potential due to exposure to chronic poverty and its co-factors (Grantham-McGregor, Cheung, Cueto, & International Child Development Steering Group, 2007). Scarcity of resources early in development contributes to restrictions in motor, cognitive, and social-emotional maturity (Aber, Bennett, Conley, & Li, 1997; Korenman, Millers, & Sjaastad, 1995; Najman et al., 2004). Scarce resources also limit the availability of trained personnel, adequate health services, and research to support appropriate interventions that could ameliorate the negative effects of early deprivation (Aikins & Marks, 2007; Olness, 2003).

Early intervention programmes in resource-limited settings would benefit from the availability of indicators of high-risk status that are simple to identify and cost-effective. The current study set out to develop an index that can be used to identify children at risk of poor developmental outcomes. For the purposes of this study, slow developmental achievement is defined as the acquisition of developmental milestones at a slower rate (<-1 SD of the group mean) than same-aged peers living in similar sociocultural and economic circumstances.

The choice of indicators to be studied here was guided by practical and theoretical considerations. For instance, low birth weight, perinatal events, and gestational age are commonly accepted as good predictors of poor developmental outcomes, but these are not suitable in communities where a significant number of children are born at home, and no accurate records of these indicators are kept (Mung'ala-Odera & Newton, 2001). On the other hand, anthropometric measures are relatively easy and cheap to administer, may act as proxy for various social, economic and health risk factors and there is a strong evidence base for their association with various childhood outcomes (de Onis, Frongillo, & Blossner, 2000; Walker et al., 2007). However, few if any studies have attempted to develop an index of risk that combines anthropometric measures with environmental factors in order to facilitate practitioners in their efforts to identify children who are most at-risk.

Conceptual and analytical framework

Our study is within the tenets of the bioecological framework (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1993), which asserts that childhood outcomes are a result of an interaction between the person and the environment. In studying ecological

Conflict of interest statement: No conflicts declared.

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Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

influences on child development various analytical approaches can be taken, including the independent-additive model, cumulative risk model, moderative model and interactive model (Krishnakumara & Black, 2002). In the current study we primarily test the independent-additive model (Aiken & West, 1991; Krishnakumara & Black, 2002). The choice of the independent-additive model as opposed to other models is motivated by both logistical and practical considerations. The independent-additive model is appropriate to the size of data set available and allows us to evaluate which of our predictors are the strongest indicators of risk, which in turn allows us to make some practical recommendations about intervention strategies.

Hypotheses

Using latent growth curve models, the current study set out to add to the literature by estimating the predictive value of various indicators of child developmental status and rate of acquisition of new milestones. In the model, we hypothesise that maternal schooling, gravidity, child health and anthropometric characteristics impact both the initial developmental status and the rate of acquisition of new milestones. Furthermore, we tested whether the combined use of multiple indicators would have greater predictive value than single indicators alone.

Method

Study site

The study took place in Kilifi, a largely rural area at the Kenyan coast. The majority of families in Kilifi depend upon subsistence farming. Harvest yields are variable due to unreliable rainfalls, which has contributed to making Kilifi District one of the poorest regions in Kenya (Ministry of Planning and Development, 2001). It is estimated that 70–80% of children in Kilifi are born at home, mostly under the supervision of untrained traditional birth attendants. Malnutrition is endemic; over 40% of children under 5 are undernourished (Maitland et al., 2006). The study took place within a demarcated area in Kilifi District that undergoes active, four-monthly demographic surveillance, in which the births, deaths, and movement of individuals are recorded.

Sampling procedures

Children representative of the normal population were sampled using stratified random sampling and recruited through five government-run clinics located across the study area. Seventy percent were recruited through four satellite clinics, two in the north and two in the south of the study area. We randomly selected an equal number of children from the areas within which each of the four clinics draws its patients (approximately 18 children per clinic). The remaining 30% ($N = 30$) were recruited at the Mother Child Health clinic located in Kilifi District Hospital, the main referral-level government hospital. Children qualified for inclusion in this study if they met the following criteria: a) aged 2 to

10 months, b) parents spoke Kiswahili or one of the Mijikenda dialects as their primary language, c) families lived within the designated study areas, and d) parent gave informed consent. A stratified sampling procedure was used; the target was to include 8–10 children per age band (defined in months) and to have an equal number of boys and girls within each age band.

Sample description

A total of 95 children (52 girls) were initially recruited; the age range was 2–10 months. Figure 1 presents a summary of the recruitment, retention and attrition at each time-point. The original data matrix contained 10 data points. Given the large number of time-points relative to the sample size, we decided not to include all time-points, but restrict the analysis to four (first, fourth, seventh, and tenth month). A child was included in the current analysis if data were available for 3 out of the 4 data points. A total of 85 (46 girls) children met these inclusion criteria

Measures

Developmental Milestones Checklist (DMC). This is a locally developed checklist that uses an interview format to assess motor, language and personal-social development of the child. The checklist was developed in the same community as part of a scheme for monthly monitoring of infants at risk. A locally developed measure was preferred over published (Western) measures because of the limitations of any individual existing instrument to adequately sample locally relevant activities. Items for the checklist were drawn from several published measures, including the Griffiths Mental Developmental Scale for Infants (Griffiths, 1954) and Vineland Adaptive Behavior Scale (Sparrow, Balla, & Cicchetti, 1984), but used locally relevant examples. Items assessing locomotor, fine motor, language

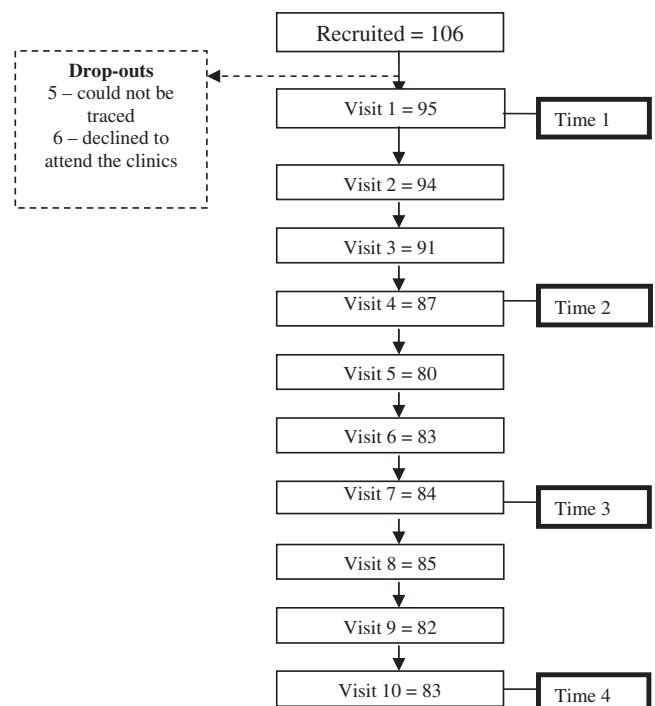


Figure 1 Recruitment and retention in the study

and personal-social development were included (see Table 1). An initial pool of 104 items was piloted with 63 mothers, randomly selected from the community. A panel consisting of six early childhood assessors and two psychologists discussed responses item by item. Items were evaluated on a) clarity (any item that was ambiguous was discarded); b) cultural appropriateness; c) age appropriateness; and d) ease of expression and translatability into the local language. The final checklist contained 66 items. Responses were given on a three-point scale (0: not observed, 1: emergent, 2: established behaviour). A trained community health worker administered the checklist in an interview with the mother. The psychometric properties of the measures (i.e., internal consistency, correlation with age and test-retest reliabilities) were checked for all time-points. The characteristics of the DMC based on the data from the first time-point are reported here ($N = 85$). The measure showed a high internal consistency ($\alpha = .94$), high retest reliability, Intraclass Correlation Coefficients (consistency coefficients = .91) and good sensitivity for age ($r(85) = .82, p < .001$). As no significant gender differences emerged ($t(85) = -.26, p = .79$), this variable was not included in further analyses.

Anthropometric measures. Height and weight measures were taken. Height was measured prone. Weights of undressed children were taken on a SECA Digital Scale. Weights were taken and recorded to one decimal point. To ensure reliability we repeated the measurement twice. Height-for-Age (HAZ) and Weight-for-Age (WAZ) scores were generated using the WHO software for assessing growth and development (World Health Organization, 2009). Measures used in this analysis are based on the data collected at the first time-point.

Maternal schooling. This measure assesses the mother's exposure to formal schooling. A dichotomous schooling variable (schoolled vs. unschooled) was created. Schoolled was defined as having attended at least one year of formal schooling.

Child ill-health. Based on a mother's report of symptoms and hospital records, when available, a consultant paediatrician graded the severity of the illness on a five-point scale: 0: not ill ($N = 4$); 1: minor childhood illness ($N = 74$); 2: major childhood illness ($N = 5$); 3: chronic illness ($N = 1$); and 4: neurological disorders ($N = 1$). We computed frequency of illness based on number of months the mother reported the child was ill; this did not take into consideration number of days child was ill. The frequencies of reported ill-health and severity of illness were multiplied to derive the children's ill-health score.

Gravidity. This measure assesses the number of times the mother has been pregnant.

Procedure

Children were seen every month (for a total of 10 months) at a clinic appointment accompanied by their mothers. During these visits, anthropometric measures were taken alongside parental reports of the child's acquisition of developmental milestones and health in the past month. When the parent failed to attend the scheduled assessment session, the community health visitor went to the home to interview the mother to be informed about the reason for the absence and to elicit consent to attend future visits. Mothers were provided with the fare to and from the clinic. The Kenya Medical Research Institute National Scientific and Ethical Committees approved the study. Written informed consent was obtained from all families and guardians of study participants.

Data management and analysis strategies

Data were double entered in FoxPro and verified before being transferred to SPSS for analysis. Means were computed to derive the descriptive statistics for each variable. Latent growth curve modelling (LGM) using Amos 5 (Arbuckle, 2003) was used to test the hypotheses stated above. LGM is considered a robust technique for the analysis of longitudinal data that allows for incomplete data at any time-point. Growth curve models create regression lines for each child's developmental achievements over time. Two latent factors are estimated; the first represents the child's baseline developmental status (the intercept) and the second represents the rate of change over time (the slope). To represent the child's baseline developmental status, the children's intercept factors were created at a fixed loading of 1 at each time-point. To represent the children's change in developmental status over time, a slope factor was created with a fixed loading of 0 for time-point 1, 1 for time-point 2, 2 for time-point 3 and 3 for time-point 4. Additional analyses, not reported here, indicated that the inclusion of curvilinear components did not add to the predictive power of the model. We used full information maximum likelihood estimation, estimates of means, and intercepts since there were missing data at each time-point. The fit of the overall model was evaluated using the chi-square statistic, which tests the exact fit of the model, as well as various other fit indices such as the root mean square of approximation (RMSEA), which measures the discrepancy between the predicted and observed models per degree of freedom.

The ages of the children within a time-point were not homogenous. These age differences were confounding variables in our design. As we were only interested in defining the influence of potential risk factors, linear regression analysis was carried out to correct for initial age differences. The standardised residuals from this

Table 1 Description of the items in the Developmental Milestones Checklist

Name of subscale	Skills assessed	Items
Motor	Head control, sitting, crawling, walking, running, kicking, throwing, reaching, object manipulation, picking, grasping and writing	28
Language	Pre-speech, gesture use, use of single words, object naming and recognition	11
Personal-social	Reaction to others, recognition of others, self-recognition, daily living skills	27

analysis were used as the individual scores for each child in the model.

We conducted two sets of analyses to determine whether the use of the combined risk indicators of developmental outcome yielded a better prediction than the use of individual indicators alone. In addition, we wanted to determine which indicator was the best predictor of both initial status and of change. The first set of analyses addressed the predictive value of each predictor alone whereas the second model tested the effect of the combined predictors. The predictive value of each predictor was expressed in terms of standardised regression weights (β coefficient), whose values represent the path coefficient between the predictor and the slope or intercept. Additionally, the amount of variance explained by a model (i.e., R^2 of both intercept and slope) was considered in judging the value of the model.

Results

Sample characteristics

The mean ages of the children (in months) for each time-point were as follows: Time-point 1: $M = 7.20$ ($SD = 2.58$, range 2.66–12.06); Time-point 2: $M = 10.22$ ($SD = 2.60$, range = 5.65–14.72); Time-point 3: $M = 13.42$ ($SD = 2.60$, range = 8.80–17.70); Time-point 4: $M = 16.16$ ($SD = 2.57$, range = 11.83–20.47). There were relatively few missing data in this analysis (time-point 1: 0%; time-point 2: 3.5%, $N = 3$; time-point 3: 2.4%, $N = 2$; time-point 4: 3.5%, $N = 3$). An attrition analysis indicated no significant differences in age ($t(95) = -.83$, $p = .42$), gender ($\chi^2(1, N = 93) = .13$, $p = .72$), and initial developmental status ($t(95) = -.55$, $p = .58$) of children who dropped out compared to those in the final analysis.

A slow rate of developmental achievement was defined as having a score below -1 SD of the group scores across the 4 data points. To determine group scores across the 4 data points an exploratory factor analysis was carried out on the child developmental scores from wave 1 to wave 4. The factor analysis identified a single strong factor which explained approximately 62.9% of the variance with a factor loading ranging from .70 to .86. Based on this definition 16.5% ($N = 14$) of the children can be classified as experiencing a slow rate of developmental achievement.

Stunting and being underweight were defined as having a score below -2 SD of the WHO standards (de Onis, Garza, Onyango, & Rolland-Cachera, 2009;

Onyango et al., 2007; World Health Organization, 2009). Based on these definitions, 28.2% ($N = 24$) and 20% ($N = 17$) were stunted and underweight, respectively; and 11.5% ($N = 13$) of the children were both stunted and underweight at the first time-point. The mean HAZ and WAZ for this population were below the WHO standard, $M = -1.27$ ($SD = 1.52$, range: -6.11 , 1.74) and $M = -1.04$ ($SD = 1.03$, range: -4.98 , 1.47), respectively. No gender differences were observed in the HAZ and WAZ of the children in this population, $t(83) = .86$, $p = .39$ and $t(83) = 1.19$, $p = .24$.

Thirty-six percent of the mothers ($N = 31$) were unschooled. The mean years of school attendance of the schooled mothers was 5.64 ($SD = 2.53$; range: 1–12 years). The mean gravidity was 3.96 ($SD = 2.54$, median = 4, range: 1–14).

A steady increase was seen in the means of the developmental scores at each time-point [time-point 1: $M = .68$ ($SD = .24$); time-point 2: $M = .98$ ($SD = .24$); time-point 3: $M = 1.27$ ($SD = .22$); time-point 4: $M = 1.50$ ($SD = .16$)]. The data indicated that children who were stunted and underweight had consistently lower mean scores across all the four time-points. Table 2 presents the standardised means and standard deviations for developmental functioning of the children, divided into a risk or no risk group, according to their HAZ and WAZ. Table 3 presents the correlation matrix between all variables entered in the latent model analysis.

Latent growth model with single predictor

The models with a single predictor all showed a good fit to the data except the model with maternal schooling, which showed a poor fit to the data; see Table 4 for the fit statistics. The strength and direction of prediction differed across variables; stunting was the strongest and predicted both intercept and slope.

Latent growth model with all predictors

The hypothesised model showed a non-significant chi-square value, $\chi^2(18, N = 85) = 20.91$, $p = .28$, $\chi^2/df = 1.16$; Tucker Lewis Index (TLI) of .95 (recommended $\geq .90$) and the RMSEA of .04 (recommended $\leq .06$), indicating a good fit of the data to the hypothesised model. However, several paths were not significant; these involved the path from mo-

Table 2 Age standardised developmental means and standard deviations for stunted, and being underweight each time-point

Variable	Time-point 1			Time-point 2			Time-point 3			Time-point 4		
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>
<i>Height-for-age</i>												
Stunted ^a	24	-.68	.92	23	-.51	.94	24	-.57	1.00	23	-.14	1.14
Normal	61	.29	.90	59	.18	.96	59	.24	.91	59	.10	.89
<i>Weight-for-age</i>												
Underweight ^a	17	-.80	.89	17	-.67	.79	17	-.76	1.12	15	-.50	1.16
Normal weight	68	.22	.92	65	.15	.98	66	.20	.87	67	.15	.88

N = Number. *M* = Mean. *SD* = Standard Deviation ^astunted/underweight is defined as a score at least 2 *SD* below the mean.

Table 3 Correlations between key variables in the model

		1	2	3	4	5	6	7	8
1	Wave 1	1							
2	Wave 2	.46**	1						
3	Wave 3	.47**	.56**	1					
4	Wave 4	.31**	.49**	.61**	1				
5	Underweight	-.41**	-.34**	-.39**	-.26**	1			
6	Stunted	-.44**	-.31**	-.37**	-.11	.53**	1		
7	Child ill health	-.27**	-.20*	-.44**	-.35**	.27**	.18*	1	
8	Maternal schooling	-.14	-.03	-.16	.21*	.17	.23*	.00	1
9	Gravidity	-.14	-.16	.02	.08	-.04	-.09	.07	-.11

* $p < .05$; ** $p < .01$ level (1-tailed).

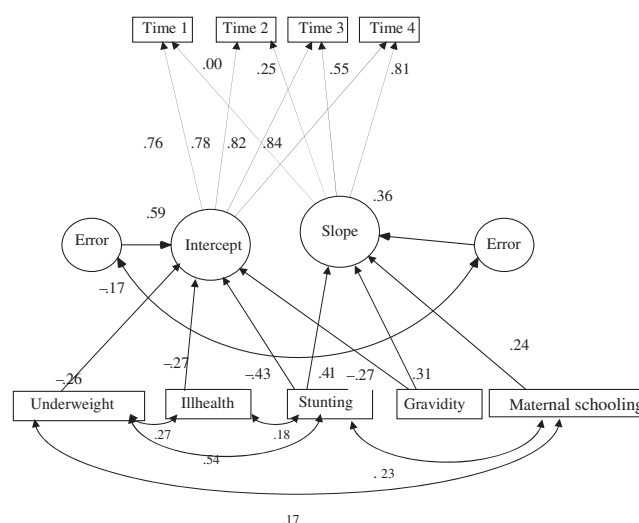
Table 4 Parameters of the single model predictors of outcome

Predictors	Intercept		Slope		χ^2	χ^2 / df	P	TLI	RMSEA
	β	R^2	β	R^2					
Stunting	-.62	.38	.45	.20	5.28	1.05	.38	.99	.03
Underweight	-.55	.30	.22	.05	3.51	.70	.62	1.04	.00
Child's health	-.34	.11	-.16	.03	6.90	1.38	.23	.95	.07
Gravidity	-.21	.04	.33	.11	3.75	.75	.58	1.04	.00
Mother's schooling	-.24	.06	.41	.17	11.96	2.39	.04	.79	.13

ther's schooling to intercept, where $\beta = -.07$, $p = .54$; children's ill-health to intercept, $\beta = -.21$, $p = .07$; children's ill-health to slope, $\beta = -.19$, $p = .20$; and underweight to slope, $\beta = -.00$, $p = .99$. The model therefore was modified by excluding non-significant paths one by one, starting with the path with the largest p -value. After excluding the first three non-significant paths (i.e., being underweight to slope, mothers' schooling to intercept and children's ill health to slope), the remaining predictor variables were all significant. The modified model continued to show a good fit, $\chi^2(21, N = 85) = 23.00$, $p = .33$, $\chi^2 / df = 1.09$, TLI = .97 and RMSEA = .03 (see Figure 2 for final model).

Both the baseline developmental status (intercept) and the rate of developmental change (slope) were significantly predicted by the model ($R^2 = .59$ and .37, respectively). These values account for a much larger proportion of the variance than found in any of the single-predictor analyses (range R^2 intercept: .06–.38; range R^2 slope: .03–.20). Therefore, it is concluded that the combination of the risk factors has greater predictive power for identifying at-risk children than any of the single predictors alone.

We also carried out analyses, not documented here, of the same model with different predictors. In that analysis maternal schooling, HAZ and WAZ were included as continuous variables. This model had good fit indices but the continuous variables were not predictive of slope or intercepts. In contrast, categorical variables of mothers' schooling, gravidity and stunting were found to predict the rate of achieving developmental milestones (slope) ($\beta = .24$, $p = .05$, $\beta = .31$, $p < .005$ and $\beta = .41$, $p < .005$) respectively. Being underweight, ill health, (higher) gravidity and stunting predicted initial developmental status (intercept), $\beta = -.26$, $p < .01$, $\beta = -.27$,

**Figure 2** Model with predictors and their standardised regressions

Note: All coefficients in the model are significant, with the exception of the (fixed) loading of zero of the slope on the first time-point ($p < .05$).

$p < .01$ $\beta = -.27$, $p < .01$, and $\beta = -.43$, $p < .001$. The regression coefficients indicated that stunting was the most powerful predictor of both intercept and the slope. This indicates that dichotomous variables were more sensitive than continuous variables in identifying children at risk of developmental delay.

Discussion

Our findings indicate that stunting, being underweight, frequency and severity of ill-health in the child, maternal lack of schooling and higher gravidity can be used to identify children who are at high risk of a slow rate of developmental achievement in sub-Saharan Africa. Each of the five indicators pre-

dicts developmental outcome, although the strength and the pattern of prediction differ. Furthermore, and consistent with experience elsewhere, the pattern of results suggests that using a combination of indicators provides the best predictive power of poor outcome (Evans & English, 2002; Sameroff, 1998; Sameroff & Chandler, 1975).

Among the indicators of risk studied, stunting was found to be the strongest predictor of developmental outcome, with the largest amount of variance explained. It predicts both the initial developmental status and the rate at which new skills are achieved. This confirms earlier studies which show that stunting is an important risk factor for the developmental outcome of children (Grantham-McGregor, 2002; Grantham-McGregor et al., 2007). The strong influence of stunting may result from the fact that it is an indicator of chronic undernutrition, which may have started prenatally.

Gravidity did not correlate with any of the other predictors entered in the model; and in the combined, it was the second strongest predictor of outcome. Our data indicate that the higher the gravidity of the mother, the higher the risk of poor outcome in the child. Gravidity may be associated with maternal and familial characteristics such as maternal age and health, amount of parental investment in child care, and the quality and quantity of stimulation at home (Andrade et al., 2005; Lawson & Mace, 2008). Moreover, higher gravidity is also associated with higher-risk pregnancies resulting in prematurity, maternal (pre)eclampsia and low birth weight among others, which result in an increased risk for developmental problems of the infants (de Sanjose & Roma, 1991; Garn & Sullivan, 1995). Large, prospective studies may be able to disentangle these relationships further and provide details regarding mechanisms underlying gravidity influences.

Maternal schooling had an inconsistent relationship with outcome, predicting the slope but not level of achievement at any time-point. It has been previously proposed that the significant influence of maternal schooling results from the use of more effective childrearing practices, greater access to treatment and preventive services and increased contributions to household income by more educated mothers (Desai & Aka, 1998; Semba et al., 2008; Wachs, 2008). There may have been too limited variation in schooling levels in the mothers included in this study, with just 6% of the mothers having more than primary school education, to find a consistent effect of schooling. The implication here may be that even those with more schooling experience may not have gained enough to significantly change parenting practices. Secondly, increased awareness and knowledge of the child's needs may have limited impact in conditions of extreme poverty, where mothers have no access to resources to implement their knowledge. Thus the influence of maternal schooling on developmental outcomes may

be mediated through other variables such as HAZ and WAZ, as has been observed with slightly older children in this population (Abubakar et al., 2008).

The positive correlation between rates of development and predictors observed, suggesting more developmental achievements in children who are stunted or whose mothers have less schooling or higher gravidity, could be explained by a combination of factors. Firstly, those children who started with higher scores had less room for improvement. Although no child achieved the highest possible total developmental score, a few were observed to achieve near maximum on the motor scales. The apparent catch-up of those children who were delayed in achieving the initial milestones was therefore likely to be partial because of a potential ceiling effect. Growth faltering in children post weaning may be another reason for this observation. In data not reported here, our analysis of WAZ and HAZ scores indicated that the proportion of children who are growth restricted increased for the last time-points. Increased post-weaning growth restriction may have compromised the achievement of development milestones, leading to shrinking of scores over time.

We used a locally developed measure of developmental outcome in this study. On the whole the measures indicated adequate reliability and validity. However, the high alpha for a multidimensional scale requires further explanation, since it may suggest that the skill areas are not differentiated or perhaps not recognised. However, given the age range of children we studied, this is not unexpected since developmental progress in different skill areas of the majority of the children at this young, largely pre-vocal, age will indeed progress in parallel. This uniformity often is indicated in high internal consistency and correlation coefficients in the scores from different domains in measures of early childhood (Bayley, 1993; Griffiths, 1954; Kerstjens et al., 2009). No normative data are available for our local instrument. As a consequence, no reference data are available from which we can derive which proportion of the children showed developmental delays. Yet, studies with comparable samples in sub-Saharan Africa have shown developmental impairments in 3–4% of the children (Maulik & Darmstadt, 2007; Muga, 2003; Mung'ala-Odera et al., 2004; Solarsh & Hofman, 2006). The figures of the present study are fairly comparable to these findings if we use common definitions; 4.7% of the children showed a cognitive impairment, defined as the score lower than -2 SD under the group average, and 11.8% a developmental delay, defined as a score between -2 and -1 SD under the group average.

The main purpose of the present study was to identify simple, yet valid indicators of developmental outcome to be used in resource-poor settings. Our data suggest that health workers and those charged with identifying and supporting children with special needs can use anthropometric data, as well as infor-

mation on family characteristics and the child's health status, as efficient screening tools. Our analysis indicated that using data collected every 3 months gives adequate information on the developmental trajectory, such that identifying and monitoring at-risk infants need not lead to excessive financial burdens in already overstretched health systems in resource-limited settings. The indicators used in combination explain a significant amount of variance to be useful from a practical perspective. The model presented here explains up to 59% of the variance at the initial time of assessment and up to 37% of the variance in the rate of achieving developmental milestones. The path model was successful in statistically predicting developmental outcomes; however, it does not specify the mechanisms that produce the poor outcomes. Future efforts aimed at understanding the underlying mechanism may be of great theoretical and practical value.

Based on these results we provide four recommendations relating to early intervention:

- a) There is a need to combine multiple indicators for the identification of at-risk children.
- b) Children who are stunted should receive the highest priority in terms of monitoring and intervention when only limited resources are available.
- c) Interventions that aim at improving physical development in the early years have the potential to improve developmental outcomes (Engle et al., 2007; Grantham-McGregor, Powell, Walker, Chang, & Fletcher, 1994; Grantham-McGregor, Powell, Walker, & Himes, 1991).

d) Growth monitoring programmes should expand the focus of monitoring to include:

- i. fetal growth, including monitoring maternal nutrition, given the possibility that stunting may have prenatal origins;
- ii. post-weaning growth, given the increase in growth restriction observed later in the first year and early in the second year and the accompanying restriction in developmental scores.

Acknowledgements

This paper is published with permission of the Director of KEMRI. Amina Abubakar and Penny Holding were supported by NIMH Fogarty R21 award (Grant MH72597-02). C.R.J.C. Newton was funded by the Wellcome Trust, UK. The authors would like to thank G. Bomu, L. Mbonani, R. Kalu, B. Kabunda, R. Mapenzi, C. Mapenzi, P. Nzai, J. Maitha, M. Mwangome and K. Rimba for their role in data collection, and K. Katana and P. Kadii for data entry. We would also like to thank the hospital staff and the different clinics where we worked for their support and assistance during the data collection period. Our sincere gratitude goes to the families that participated in this study, who generously gave their time to make this work possible.

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Key points

- Stunting, being underweight, little maternal schooling and a child's history of ill-health each puts the child at risk of a slow rate of developmental achievements.
- An index of risk status that combines stunting, being underweight, gravidity, little maternal schooling and a child's history of ill-health provides a cost-effective approach for identifying children at risk of a slow rate of developmental achievements in resource-poor settings.
- In cases where resources are very limited, children who are stunted should receive the highest priority in preventive care.
- We have identified a relatively easy-to-administer and cost-effective approach for selection of children in need of monitoring and intervention.

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Manuscript accepted 11 September 2009